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NSWC TR 88-382

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## USER INSTRUCTIONS FOR THE EPIC-2/REZONE CODE

BY R.A. STRYK AND G. R. JOHNSON  
(HONEYWELL, INC./ARMAMENT SYSTEMS DIVISION)

FOR NAVAL SURFACE WARFARE CENTER  
RESEARCH AND TECHNOLOGY DEPARTMENT

SEPTEMBER 1987

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## REPORT DOCUMENTATION PAGE

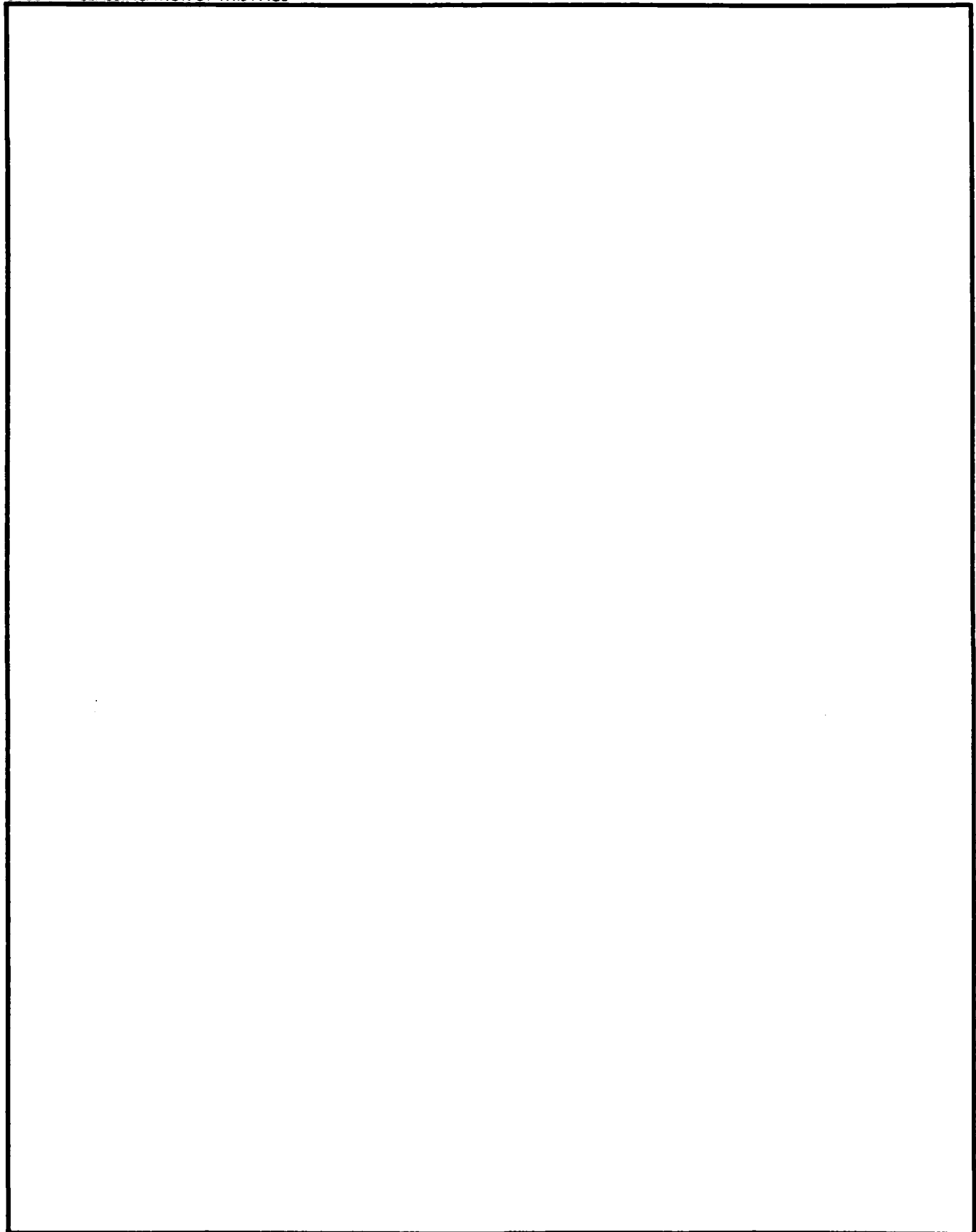
1a. REPORT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>			1b. RESTRICTIVE MARKINGS																	
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.																	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE																				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) <b>32824</b>			5. MONITORING ORGANIZATION REPORT NUMBER(S) <b>NSWC TR 88-382</b>																	
6a. NAME OF PERFORMING ORGANIZATION <b>Honeywell Inc. Armament Systems Division</b>		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION <b>Naval Surface Warfare Center</b>																	
6c. ADDRESS (City, State, and ZIP Code) <b>7225 Northland Drive Brooklyn Park, MN 55428</b>			7b. ADDRESS (City, State, and ZIP Code) <b>10901 New Hampshire Avenue Silver Spring, MD 20903-5000</b>																	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION <b>Naval Surface Warfare Center</b>		8b. OFFICE SYMBOL (If applicable) <b>Code R12</b>	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER <b>N60921-86-C-0249</b>																	
8c. ADDRESS (City, State, and ZIP Code) <b>10901 New Hampshire Avenue Silver Spring, MD 20903-5000</b>			10. SOURCE OF FUNDING NOS. <table border="1"><tr><td>PROGRAM ELEMENT NO. <b>62314N</b></td><td>PROJECT NO. <b>RJ14W21</b></td><td>TASK NO. <b>5</b></td><td>WORK UNIT NO.</td></tr></table>			PROGRAM ELEMENT NO. <b>62314N</b>	PROJECT NO. <b>RJ14W21</b>	TASK NO. <b>5</b>	WORK UNIT NO.											
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11. TITLE (Include Security Classification) <b>User Instructions for the EPIC-2/REZONE Code</b>																				
12. PERSONAL AUTHOR(S) <b>Stryk, R. A. and Johnson, G. R.</b>																				
13a. TYPE OF REPORT <b>Final</b>		13b. TIME COVERED FROM <b>11/86</b> TO <b>09/87</b>		14. DATE OF REPORT (Yr., Mo., Day) <b>1987, September</b>																
15. PAGE COUNT <b>40</b>																				
16. SUPPLEMENTARY NOTATION																				
17. COSATI CODES <table border="1"><tr><th>FIELD</th><th>GROUP</th><th>SUB. GR.</th></tr><tr><td><b>12</b></td><td><b>01</b></td><td></td></tr><tr><td></td><td></td><td></td></tr></table>			FIELD	GROUP	SUB. GR.	<b>12</b>	<b>01</b>					18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) <table><tr><td>Computer Codes</td><td>Finite Element</td></tr><tr><td>Jet Formation</td><td>Computations</td></tr><tr><td>Rezoning</td><td></td></tr></table>			Computer Codes	Finite Element	Jet Formation	Computations	Rezoning	
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<b>12</b>	<b>01</b>																			
Computer Codes	Finite Element																			
Jet Formation	Computations																			
Rezoning																				
19. ABSTRACT (Continue on reverse if necessary and identify by block number) <p>This report provides user instructions for the 1987 version of the EPIC-2 REZONE code. It can be used in conjunction with the 1986 version of EPIC-2. This rezone code was developed primarily for jet formation computations, but it should also be useful for other applications. Example problems are included to demonstrate its capabilities.</p>																				
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>																	
22a. NAME OF RESPONSIBLE INDIVIDUAL <b>Paula Walter</b>		22b. TELEPHONE NUMBER (Include Area Code) <b>(301) 394-2714</b>		22c. OFFICE SYMBOL <b>Code R12</b>																

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## FOREWORD

This report on the EPIC-2/REZONE computer code was prepared by Honeywell Inc., Armament Systems Division, 7225 Northland Drive, Brooklyn Park, Minnesota 55428, for the White Oak Laboratory, Naval Surface Warfare Center (NSWC), 10901 New Hampshire Avenue, Silver Spring, Maryland 20903-5000, under contract N60921-86-C-0249.

This effort was conducted during the period from November 1986 to September 1987. The authors would like to thank Paula Walter, NSWC program manager, and Drs. Kibong Kim and Frank Zerilli for helpful technical discussions during the course of this program.

The modification of the EPIC-2 Postprocessor, to include node number plotting, was performed with Honeywell Independent Development funding.

Approved by:

*Kurt F. Mueller* Acting for

DR. KURT F. MUELLER, Head  
Energetic Materials Division

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## SECTION 1

### INTRODUCTION

This report provides user instructions for the 1987 version<sup>1</sup> of the EPIC-2/REZONE code for use with the 1986 version of the EPIC-2 code. Use is restricted to two-dimensional geometry (axisymmetric, plane strain, plane stress), and only triangular elements can be rezoned.

The primary motivation for this work was the desire to be able to rezone computations involving explosive-metal interaction and subsequent jet formation. It should be useful for other applications.

There are two primary reasons for rezoning. One is to improve accuracy and the other is to decrease computing time through use of a larger integration time increment. When triangular elements become very distorted (long and slender) they may not be able to properly represent gradients along the longer dimension of the element, and this can lead to artificial stiffness. Similarly, during high distortion the minimum altitude of the element can become very small and this decreases the integration time increment, which is bounded by the sound speed transit time across the element. Rezoning allows the user to replace distorted elements with compact elements; decreasing the larger dimension gives greater accuracy, and increasing the shorter dimension gives a larger integration time increment.

There are two separate functions performed in the EPIC-2/REZONE code. The first is to delete the distorted grid and to replace it with a better grid (more compact elements). The second function is to transfer the physical properties (node and element variables) from the old grid to the new grid. This second function is performed automatically without user intervention.

The remainder of this report provides a brief description of the approach, user instructions and examples.

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<sup>1</sup>Johnson, G.R. and Stryk, R.A., User Instructions for the EPIC-2 Code, AFATL-TR-86-51, Honeywell Inc., Defense Systems Division, Edina, MN, Sep 1986.

## SECTION 2

### APPROACH

This section provides a brief overview of how the EPIC-2/REZONE code works. The following is a list of the primary functions performed by the code.

- The EPIC-2/REZONE code reads the restart file which must have been previously generated by the EPIC-2 code.
- The element variables from the restart file are transferred to nodal quantities. For example, the nodal pressure is the average of the element pressures for all elements attached to a specified node.
- Portions of the old grid (from restart file) are deleted and the new grid is generated. The node and element variables from the old grid are saved in temporary arrays.
- Each new node searches through the old grid to find the appropriate old element which contains the position of the new node.
- The velocities and accelerations for the new node are linearly interpolated from the old nodal velocities and accelerations of the three old nodes which define the old element which contains the new node.
- The center position of each new element searches through the old grid to find the appropriate old element which contains the center position of the new element.
- The variables for the new element are linearly interpolated from the old nodal quantities of the old element variables.
- The new grid, with node and element variables interpolated from the old grid, is written on a restart file. This new restart file is then available to be read by the EPIC-2 code for further computations.

It should be noted that there is no absolute conservation of mass, momentum or energy. If, however, the outline of the new grid closely coincides with the outline of the old grid, then these system parameters should be closely matched (within a few percent). Significant discrepancies in the outlines of the old and new grids can lead to significant discrepancies in the mass, momentum and energy. The user should compare the summaries of the system data output for the grid before and after rezoning, to ascertain the accuracy of rezoning.



### SECTION 3

#### USER INSTRUCTIONS

This section provides user instruction for the EPIC-2/REZONE code. The function of this is to read a restart file, define a new geometry, transfer physical properties to the new geometry, and write a restart file. If the rezoning performed with this program requires changes in slide lines, etc., these changes must be made with the Change Drop and Change Add options in EPIC-2.

#### INPUT DATA FOR EPIC-2/REZONE

The input data necessary to perform the rezoning are shown in Figures 1 through 3 and Reference 1. The descriptions which follow are for the data in Figures 1 through 3. The units used must be the same as those used for the EPIC-2 preprocessor input.

It is possible to interject user comments into the data by use of a \$ character. If the \$ is in the first column of the card, that entire card is ignored as input data. If the \$ is beyond the first column in the card, then the \$ and all data to the right of the \$ are ignored.

Before continuing, note the following definitions:

- A "deleted node" is a node from the original grid (before rezoning) which has been deleted. There are some instances when the coordinates of a deleted node are used.
- An "old node" is a node from the original grid (before rezoning) which has not been deleted and remains a part of the grid after rezoning occurs.
- A "new node" is a node which is introduced into the rezoned grid.
- A "previously generated new node" is a node which was previously generated during the current rezoning activity. There are some instances when a "new node" may make use of the coordinates of a "previously generated new node," when two adjacent shapes are being generated.

#### Description Card (A80)

**TITLE** = Title for report.

**Miscellaneous Card (715)**

**CYCLE** = Cycle number on restart file which will be rezoned.

**NPROJ** = 0 will allow rezoning of projectile only.  
 1 will allow rezoning of target only.

**DESCRIPTION CARD (A80)**

TITLE
-------

**MISCELLANEOUS CARD (715)**

CYCLE	NPROJ	NGN	NGL	NNDEL	NLDEL	PRINT
-------	-------	-----	-----	-------	-------	-------

**INDIVIDUAL DELETED NODES CARD - FOR NGN = 0 (1615)**

N1	N2	....	NN
----	----	------	----

**NODE GROUP CARDS - FOR NGN > 0 (315)**

N1G	NNG	INC
-----	-----	-----

**INDIVIDUAL DELETED ELEMENTS CARD - FOR NGL = 0 (1615)**

L1	L2	....	LN
----	----	------	----

**ELEMENT GROUP CARD - FOR NGL > 0 (315)**

L1G	LNG	INC
-----	-----	-----

**NODE DATA CARDS AND ADDITIONAL NODE DATA CARDS - AS REQUIRED**

(DESCRIBED IN FIGURE 2 OF THIS REPORT AND IN FIGURE 3 OF AFATL-TR-88-51)

BLANK CARD	ENDS NODE DATA
------------	----------------

**ELEMENT DATA CARDS AND ADDITIONAL NODE DATA CARDS - AS REQUIRED**

(DESCRIBED IN FIGURE 3 OF THIS REPORT AND IN FIGURE 4 OF AFATL-TR-88-51)

BLANK CARD	ENDS ELEMENT DATA
------------	-------------------

**MERGE CARD (F10.0)**

TOLMRG
--------

FIGURE 1. EPIC-2/REZONE INPUT DATA

**FOUR-SIDED SHAPE NODE CARD (5I5,5X,F10.0)**

7	N1	NC	NL	IRFX	RELAX	
---	----	----	----	------	-------	--

**CORNER NODE DEFINITION CARDS - 4 REQUIRED (2I5,2F10.0)**

NOLD	NGEN	RCNR	ZCNR	
------	------	------	------	--

**SIDE OPTIONS CARD (4I5)**

IS1	IS2	IS3	IS4	
-----	-----	-----	-----	--

**SIDE NODE COORDINATE CARDS - AS NECESSARY (8F10.0)**

R1	R2	R3	....	RN	
----	----	----	------	----	--

Z1	Z2	Z3	....	ZN	
----	----	----	------	----	--

**OLD SIDE NODES CARD(S) - AS NECESSARY (16I5)**

NO1	NO2	NO3	.....	NON	
-----	-----	-----	-------	-----	--

**GENERATED SIDE NODES CARD(S) - AS NECESSARY (16I5)**

NG1	NG2	NG3	.....	NGN	
-----	-----	-----	-------	-----	--

**THREE-SIDED SHAPE NODE CARD (3I5,5X,I5,5X,F10.0)**

8	N1	NRING	IRFX	RELAX	
---	----	-------	------	-------	--

**CORNER NODE DEFINITION CARDS - 3 REQUIRED (2I5, 2F10.0)**

NOLD	NGEN	RCNR	ZCNR	
------	------	------	------	--

**SIDE OPTIONS CARD (3I5)**

IS1	IS2	IS3	
-----	-----	-----	--

**SIDE NODE COORDINATE CARDS - AS NECESSARY (SEE ABOVE)**

**OLD SIDE NODE CARDS - AS NECESSARY (SEE ABOVE)**

**GENERATED SIDE NODES CARD(S) - AS NECESSARY (SEE ABOVE)**

**REGRID LINE OF NODES CARD (4I5,2X,3I1,I5)**

9	N1	NN	INC	IS1	
---	----	----	-----	-----	--

IR, IZ, IT

**CORNER NODE DEFINITION CARD (SEE ABOVE)**

**SIDE NODE COORDINATE CARDS - AS NECESSARY (SEE ABOVE)**

**OLD SIDE NODES CARD(S) - AS NECESSARY (SEE ABOVE)**

**GENERATED SIDE NODES CARD(S) - AS NECESSARY (SEE ABOVE)**

FIGURE 2. ADDITIONAL NODE INPUT DATA

**FOUR-SIDED SHAPE ELEMENT DESCRIPTION CARD (6I5)**

7	N1	MATL	L1	NCOL	NLAY										
---	----	------	----	------	------	--	--	--	--	--	--	--	--	--	--

**THREE-SIDED SHAPE ELEMENT DESCRIPTION CARD (5I5)**

8	N1	MATL	L1	NCOL											
---	----	------	----	------	--	--	--	--	--	--	--	--	--	--	--

**TRANSITION ELEMENTS DESCRIPTION CARD (16I5)**

9	N1	MATL	L1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13
---	----	------	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----

FIGURE 3. ADDITIONAL ELEMENT INPUT DATA

Note: It is possible to rezone nodes and/or elements in both the projectile and the target in a single rezone run. If it is necessary to do this, then two subsequent rezone runs must be made.

- NGN = Number of groups of elements to be deleted. If NGN = 0 then deleted nodes are read individually.
- NGL = Number of groups of elements to be deleted. If NGL = 0 then deleted elements are read individually.
- NNDEL = Number of nodes to be deleted.
- NLDEL = Number of elements to be deleted. Only elements with the same material number can be deleted.
- PRINT = 0 will provide minimal printing.  
 1 will print new nodes and elements.  
 2 will provide extensive printing for program checkout.

**Individual Deleted Nodes Card (16I5)**

The deleted nodes are input individually when NGN = 0.

N1...NN = Nodes to be deleted.

**Node Group Card (3I5)**

Use one card for each group of nodes to be deleted.

- N1G = First node in group.
- NNG = Last node in group. May be left blank if group has only one node.
- INC = Increment between nodes. May be left blank if increment is 1.

**Individual Deleted Elements Card (1615)**

The deleted elements are input individually when  $NCL = 0$ .

$L1...LN$  = Elements to be deleted.

**Element Group Card (315)**

Use one card for each group of elements to be deleted.

$L1G$  = First element in group.

$LNG$  = Last element in group. May be left blank if group has only one element

$INC$  = Increment between elements. May be left blank if increment is 1.

**Node Data Cards**

The node data cards for EPIC-2, as described in Reference 1, are acceptable as well as the cards described in Figure 2. (The Additional Node Data Cards of Figure 2 will be defined later). There is no Scale/Shift/Rotate card (as used in Reference 1) so all coordinates given must be the actual coordinate. A blank card ends the node data input.

**Element Data Cards**

The element data cards for EPIC-2, as described in Reference 1, are acceptable as well as the cards described in Figure 3. (The Additional Element Data Cards of Figure 3 will be described later.) A blank card ends the element data input.

**Merge Card (F10.0)**

The node merging function provides a way of combining adjacent shapes to cover a complex region. Each shape can be generated using the node numbering required by the node generator. Adjacent shapes may require different node numbers for the same node location. This requirement can be met by generating a node for each node number needed. After the node and element generators have been used, then the multiple nodes (at a single location) are reduced to single nodes by the node merging function.

$TOLMRG$  = Greater than zero to merge nodes which are close together. All nodes in a box ( $TOLMRG$  on each side) are combined to become the same node. The node number entered first in the node input cards will be used for the combined node. Only the newly entered nodes are merged.  $TOLMRG = 0$  gives no node merging.

**Additional Node Data Cards**

The node data cards described in Reference 1 can be used to describe the new grid but three new generators have been added to take advantage of the availability of the old grid. The new generators can use the coordinates of deleted nodes for the position of a new node. The generators can also find the edge of the deleted grid between two deleted nodes and use this line for the side of a new shape. When this edge option is used, only the approximate position of the deleted end nodes need to be

given. With these features it is possible to lay out a new grid using only a geometry state plot (See Appendix A).

#### **Four-Sided Shape Node Card (5I5, 5X, F10.0)**

The four-sided shape is shown in Figure 4. Six cards are required for each four-sided shape generated. Additional cards are needed for certain options. The corner nodes are defined in a counterclockwise direction with the first corner node being N1. The sides are defined in a counterclockwise direction. The first side starts at the first corner node and ends at the second corner node. The fourth side starts at the fourth corner node and ends at the first corner node. The nodes are numbered in layers. The first layer starts at the first corner node and goes across to the fourth corner node. The following layers go into the interior of the shape with the last layer going from the second to the third corner nodes. This shape can be made continuous with adjacent shapes by aligning border nodes and using the merge option. The RELAX option (described later) provides a method of more evenly spacing the interior primary nodes of this shape. The node placement algorithm gives good results for a rectangular shape but questionable placement for distorted shapes, especially those with curved sides. When questionable node placement occurs, the RELAX option can improve the placement. The border nodes are not moved. The interior primary nodes are moved to be at the average position of the other four connected primary nodes. The secondary nodes are generated later.

- 7           = Identification number for four-sided node shape geometry.
- N1          = Number of the first node of the four-sided shape. This should be selected so the generated new nodes do not have the same node numbers as remaining old nodes.
- NC          = Number of nodes along the second and fourth side. Does not include the secondary (crossed triangle) nodes.
- NL          = Number of nodes along the first and third side. Does not include the secondary (crossed triangle) nodes.
- IRFIX       = Radial restraint option. If IRFIX = 1, all nodes on the axis of symmetry are restrained radially. Leave blank for no restraint.
- RELAX       = Less than or equal to zero for no node motion. Greater than zero to move the interior primary nodes to the average position of the adjacent four primary nodes. The primary nodes are moved in several sweeps. Each sweep takes the interior nodes in numeric order, adjusts the node position, and sums the node movements. The sweeps terminate when the total node movement for the last sweep is less than RELAX. The relaxed four-sided shape will have more evenly spaced nodes. The secondary nodes are placed at the average position of the four primary nodes in the composite element (four crossed triangles).

#### **Corner Node Definition Cards (2I5, F10.0)**

Four cards are required, one for each corner node. The first corner node is N1. The other three corner nodes are defined in counterclockwise order.

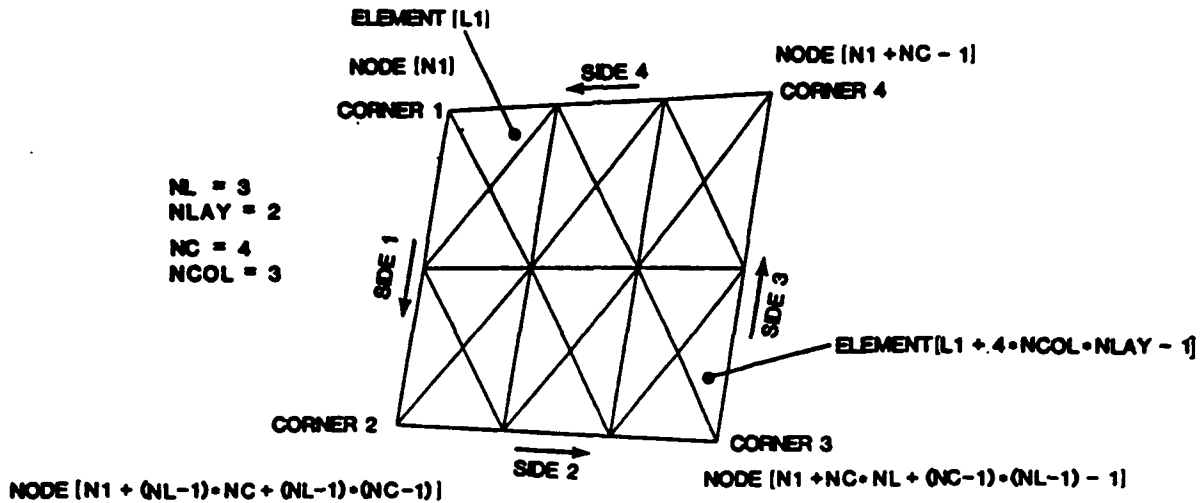


FIGURE 4. FOUR-SIDED SHAPE GEOMETRY

- NOLD** = The old/deleted node to use for coordinates. Leave blank if you do not want this option.
- NGEN** = The previously generated new node to use for coordinates. The duplication of node definitions can be removed by the merge step. Leave blank if you do not want this option.
- RCNR** = R coordinate of corner node.
- ZCNR** = Z coordinate of corner node.

Note: The R and Z coordinates are ignored when either the NOLD or NGEN option is used.

#### Side Options Card (415)

There are five options (0,1,2,3,4) for each of the four sides (IS1, IS2, IS3, IS4).

- IS1**  
**IS2**  
**IS3**  
**IS4**
- = 0 Will equally space the side nodes on a straight line between the corner nodes.
- = 1 Will equally space the side nodes on the edge of the deleted region. If the corner nodes are not already defined as old/deleted nodes on the edge, then the corner node (whose coordinates were input as RCNR and ZCNR) is moved to the closest old/deleted edge node.
- = 2 Will position the side nodes at coordinates given on the following Side Node Coordinate Cards.

- = 3 Will place the side nodes at the coordinates of the old/deleted nodes given on the following Old Side Nodes Card(s).
- = 4 Will place the side nodes at the same coordinates as the previously generated new nodes given on the following Generated Side Nodes Card(s).

Note: For side options 2, 3, and 4, an additional card (or cards) is required to define side coordinates and/or side node numbers. The side 1 option should be input first (if needed), followed by sides 2, 3, and 4.

### Side Node Coordinate Cards (8F10.0)

These cards must be input in counterclockwise order.

R1...RN = R coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

Z1...ZN = Z coordinates of the border nodes on the side. (Do not include corner nodes.) One or more cards as necessary.

### Old Side Nodes Cards (16I5)

These cards must be input in counterclockwise order.

N01...N0N = Node number of old/deleted nodes where side nodes are to be placed. (Do not include corner nodes.) One or more cards as necessary.

### Generated side Nodes Cards (16I5)

These cards must be input in counterclockwise order.

NG1...NGN = Node numbers of previously generated new nodes where the side nodes are to be placed. (Do not include corner nodes.) One or more cards as necessary.

### Three-Sided Shape Node Cards (3I5, 5X, I5, 5X, F10.0)

The three-sided shape is shown in Figure 5. Five cards are required for each three-sided shape generated. Additional cards are needed for certain options. The corner nodes are defined in a counterclockwise direction with the first corner node being N1. The sides are defined in a counterclockwise direction. The first side starts at the first corner node and ends at the second corner node. The third side starts at the third corner node and ends at the first corner node. The shape is meant to be roughly triangular. The first and third sides have the same number of nodes, NRING. The second side has more nodes,  $2 * (NRING - 1) - 1$ . The total number of nodes is  $2 * (NRING * NRING - 1)$ . The shape is composed of two regions. The first region starts at the first corner and extends to the last node before the second and third corners. The remaining region, a strip along the second side, is a strip of crossed triangles. The node numbering is also done in two regions. The first region is numbered as described for the four-sided shape. The crossed-triangle strip along the second side is numbered in a direction generally from corner three towards corner two. The secondary nodes are numbered first and the outside primary nodes are numbered last. The highest numbered node is corner two.



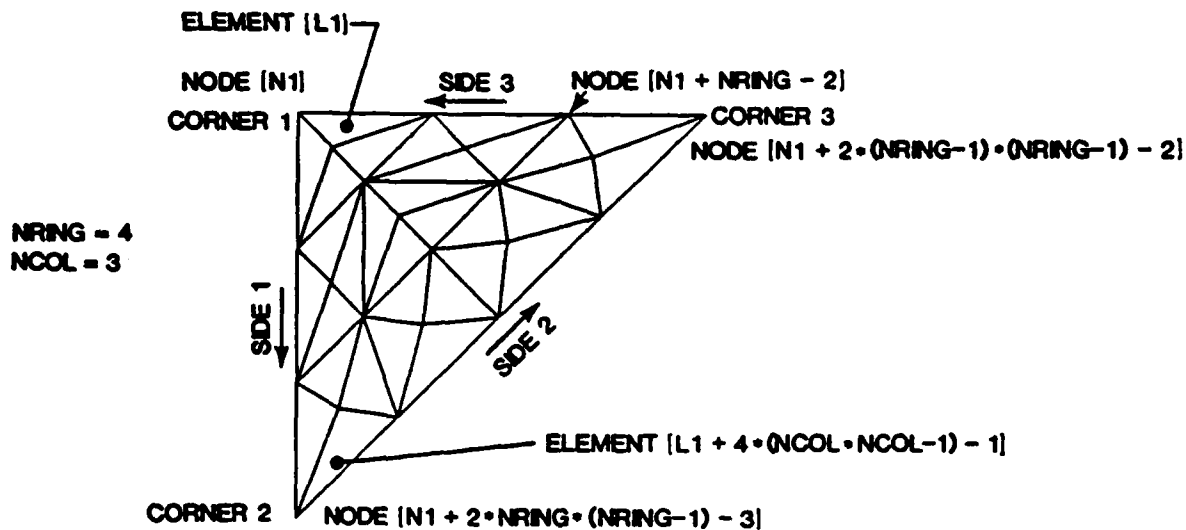


FIGURE 5. THREE-SIDED SHAPE GEOMETRY

- 8 = Identification number for three-sided shape geometry.
- N1 = Number of the first node of the three-sided shape.
- NRING = Number of nodes on two shorter sides of shape (Sides 1 and 3). Must be 3 or larger.
- IRFIX = Radial restraint option. If IRFIX = 1, all nodes on the axis of symmetry are restrained radially. Leave blank for no restraint.
- RELAX = Less than or equal to zero for node motion. Greater than zero to move the interior primary nodes to the average position of the adjacent four primary nodes. The primary nodes are moved in several sweeps. Each sweep takes the interior nodes in numeric order, adjusts the node position, and sums the node movements. The sweeps terminate when the total node movement for the last sweep was less than RELAX. The relaxed three-sided shape will have more evenly spaced nodes.

#### Corner Node Definition Cards (2I5, E10.0)

Three cards are required, one for each corner node. The first corner node is N1. The other two nodes are defined in counterclockwise order.

- NOLD = The old/deleted node to use for coordinates. Leave blank if you do not want this option.
- NGEN = The previously generated new node to use for coordinates. The duplication of node definitions can be removed by the merge step. Leave blank if you do not want this option.

**RCNR** = R coordinate of corner node.

**ZCNR** = Z coordinate of corner node.

Note: The R and Z coordinates are not needed when either the NOLD or NGEN option is used.

### **Side Option Card (3I5)**

The choice of five options (0,1,2,3,4) for each of the three sides (IS1, IS2, IS3) is the same given for the four-sided shape.

### **Side Node Coordinate Cards**

Same as given for the four-sided shape.

### **Old Side Node Coordinate Cards**

Same as given for the four-sided shape.

### **Generated Side Node Coordinate Cards**

Same as given for the four-sided shape.

### **Regrid Line of Nodes Card (4I5, 2X, 3I1, I5)**

Two cards are required if a single node is to be generated and three or more cards are required for more than one node. The nodes may be numbered consecutively or incremented by INC. New nodes can be generated using the coordinates of old/deleted nodes.

- 9** = Identification number for regrid line of nodes geometry.
- N1** = Number of the first node.
- NN** = Number of the last node of the line. Leave blank if a single node is to be generated.
- INC** = Node number increment between corresponding nodes. Leave blank for consecutive numbering or if a single node is to be generated.
- IR** = Radial restraint. If IR = 1, all nodes will be restrained in the radial direction. Leave blank for no restraint.
- IZ** = Axial restraint. If IZ = 1, all nodes will be restrained in the axial direction. Leave blank for no restraint.
- IT** = Theta restraint. If IT = 1, all nodes will be restrained in the  $\theta$  direction. Leave blank for no restraint.
- IS1** = Side option same as described for the Side Option Card above. Used only when more than 2 nodes are generated.

**Corner Node Definition Card**

Same as for the three- and four-sided shapes. One corner card required for single node generation and two corner cards required for two or more nodes generated.

**Side Node Coordinate Cards**

Same as the three- and four-sided shapes. Required only when generating three or more nodes and  $IS1 = 2$ .

**Old Side Nodes Coordinate Cards**

Same as for the three- and four-sided shapes. Required only when generating three or more nodes and  $IS1 = 3$ .

**Generated Side Nodes Coordinate Cards**

Same as for the three- and four-sided shapes. Required only when generating three or more nodes and  $IS1 = 4$ .

**ADDITIONAL ELEMENT INPUT DATA**

The element data must be input in a manner consistent with the Node Data Cards of Reference 1 and/or the Additional Node Data Cards described in this report. In addition to the four-sided and three-sided shapes, a Transition Element shape is included to assist in gridding transition regions. A description of the additional element input data, for the three new shapes, is given in Figure 3.

**Four-Sided Shape Element Description Card (6I5)**

One card is required for each four-sided shape, as shown in Figure 4. The elements are numbered consecutively, beginning with the layer along side 4 (from corner 1 to corner 4), and ending with the layer along side 2 (from corner 2 to corner 3). The number of elements generated is  $4*NCOL*NLAY$ .

- 7           = Identification number for four-sided shape geometry.
- N1          = Number of first node in four-sided shape.
- MATL       = Material number for the elements. Must be identical to the deleted material.
- L1          = Number of the first element in the four-sided shape.
- NCOL       = Number of columns of composite elements (four crossed triangles) along sides 2 and 4.
- NLAY       = Number of layers of composite elements (four crossed triangles) along sides 1 and 3.

**Three-Sided Shape Element Description Card (515)**

One card is required for each three-sided shape, as shown in Figure 5. The element numbering follows the pattern of node numbering. The first region is numbered first and the strip along the second side is numbered from the third corner towards the second corner. The number of elements generated is  $4 * (\text{NRCOL} * \text{NRCOL} - 1)$ .

- 8 = Identification number for three-sided shape geometry.
- N1 = Number of first node in three-sided shape.
- MATL = Material number for the elements. Must be identical to the deleted material.
- L1 = Number of first element in three-sided shape.
- NCOL = Number of composite elements (four crossed triangles) along sides one and three.

**Transition Elements Description Card (1615)**

One card is required for each group of transition elements, as shown in Figure 6. The group has a central node and form 3 to 12 elements around the central node.

- 9 = Identification number for transition geometry.
- N1 = Number of the central node.
- MATL = Material number for the elements. Must be identical to the deleted material.

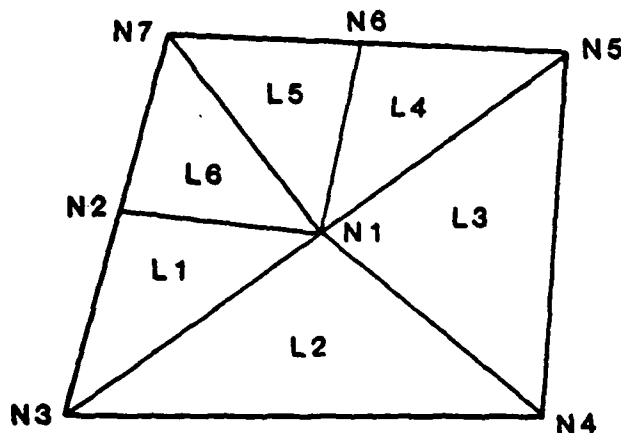


FIGURE 6. TRANSITION SHAPE GEOMETRY

- L1** = Number of the first element. The first element will be composed of the nodes N1, N2, and N3. The second element will be N1, N3, and N4. The last element will be N1, NK, and N2 where NK is the last non-blank perimeter node given.
- N2..N13** = Numbers of the perimeter nodes. At least 3 nodes must be given. The order of the nodes must be counterclockwise. Newly generated nodes and old (undeleted) nodes may be used.

## PROGRAM STRUCTURE AND FILE DESIGNATION

A hierarchy chart for EPIC-2/REZONE is shown in Figure 7. Many of the subroutines are identical to those of EPIC-2. Table 1 contains a list of the modified and unmodified EPIC-2 subroutines.

The file designations are as follows:

- IN** = 5 Input file
- IOUT** = 6 Output file
- ITAPIN** = 9 Restart tape read by REZONE
- ITAPOT** = 10 Restart tape generated by REZONE

TABLE 1. EPIC-2 SUBROUTINES USED IN EPIC-2/REZONE

Modified	Unmodified
ECORE	ECOUNT
ESHAPE	NEWMAS
NBCORE	NFIX
NCORE	RECALL
NSHAPE	SAVE
	SDATA

## INSTRUCTIONS FOR CHANGING PROGRAM DIMENSIONS

All the arrays which have their dimension changed are in COMMON statements with the dimension given by a parameter. Each COMMON statement and its associated PARAMETER statement is in a VAX style INCLUDE file. A complete

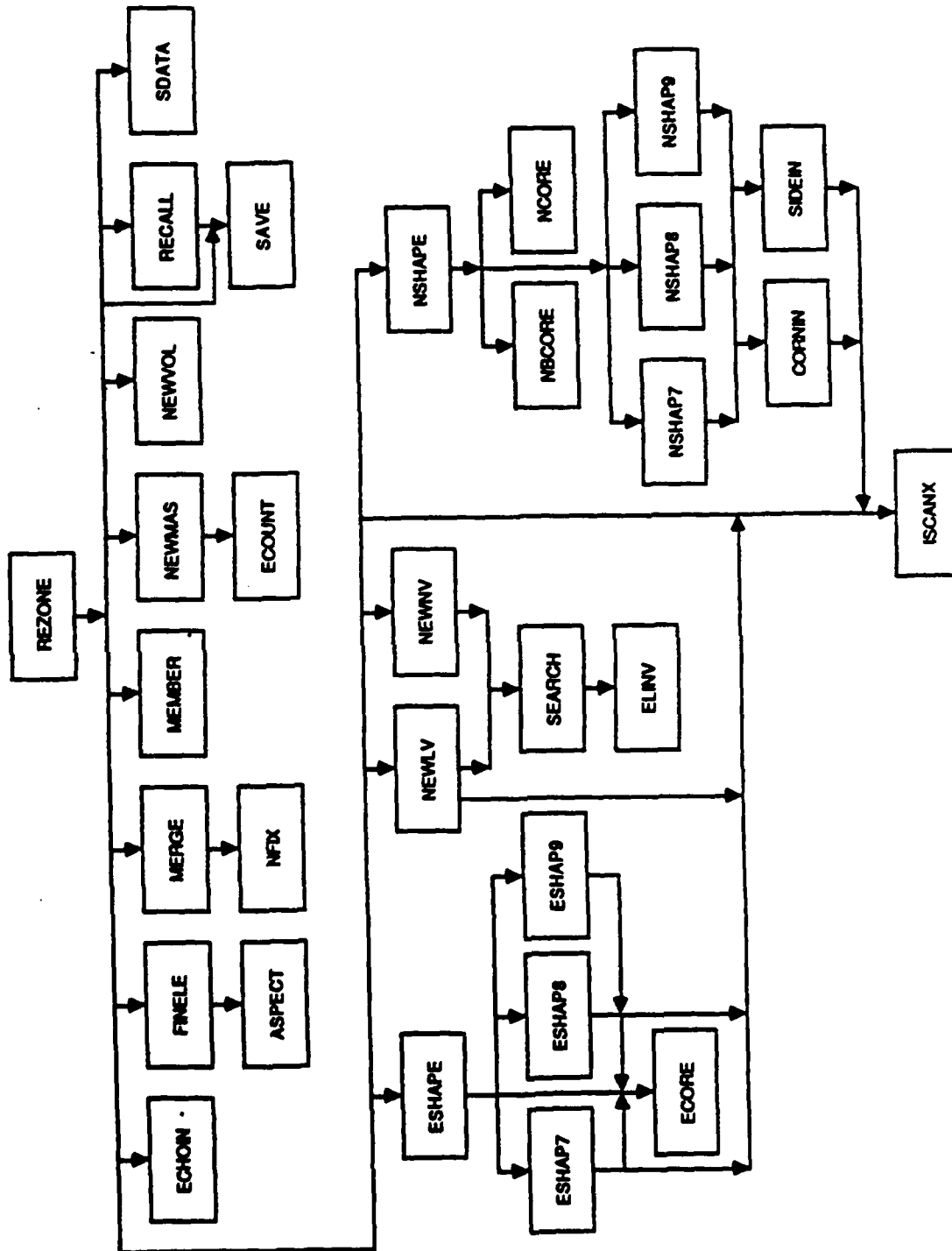


FIGURE 7. HIERARCHY CHART FOR EPIC-2/REZONE

list of all the COMMON statements can be found in the BLOCK DATA subprogram RZINIT. A program dimension can be changed by editing the PARAMETER statement in an include file and recompiling the program. A comment explaining the meaning of each parameter follows each PARAMETER statement.

All instructions for changing the program dimensions of EPIC-2 apply here also except the DATA statement in subroutine GEOM has been moved to RZINIT. The arrays in EPIC-2/REZONE must be large enough to contain the problem handled by EPIC-2. A safe way to approach this is to have corresponding arrays in both programs the same size.

## EXAMPLE PROBLEMS

Figure 8 shows three computations of a copper cylinder impacting a rigid surface. In Case A there is no rezoning, in Case B there is a rezone at 10 $\mu$ s, and in Case C there are rezones at 10 $\mu$ s and 20 $\mu$ s. In all three cases, the computations were performed for a total of 80 $\mu$ s.

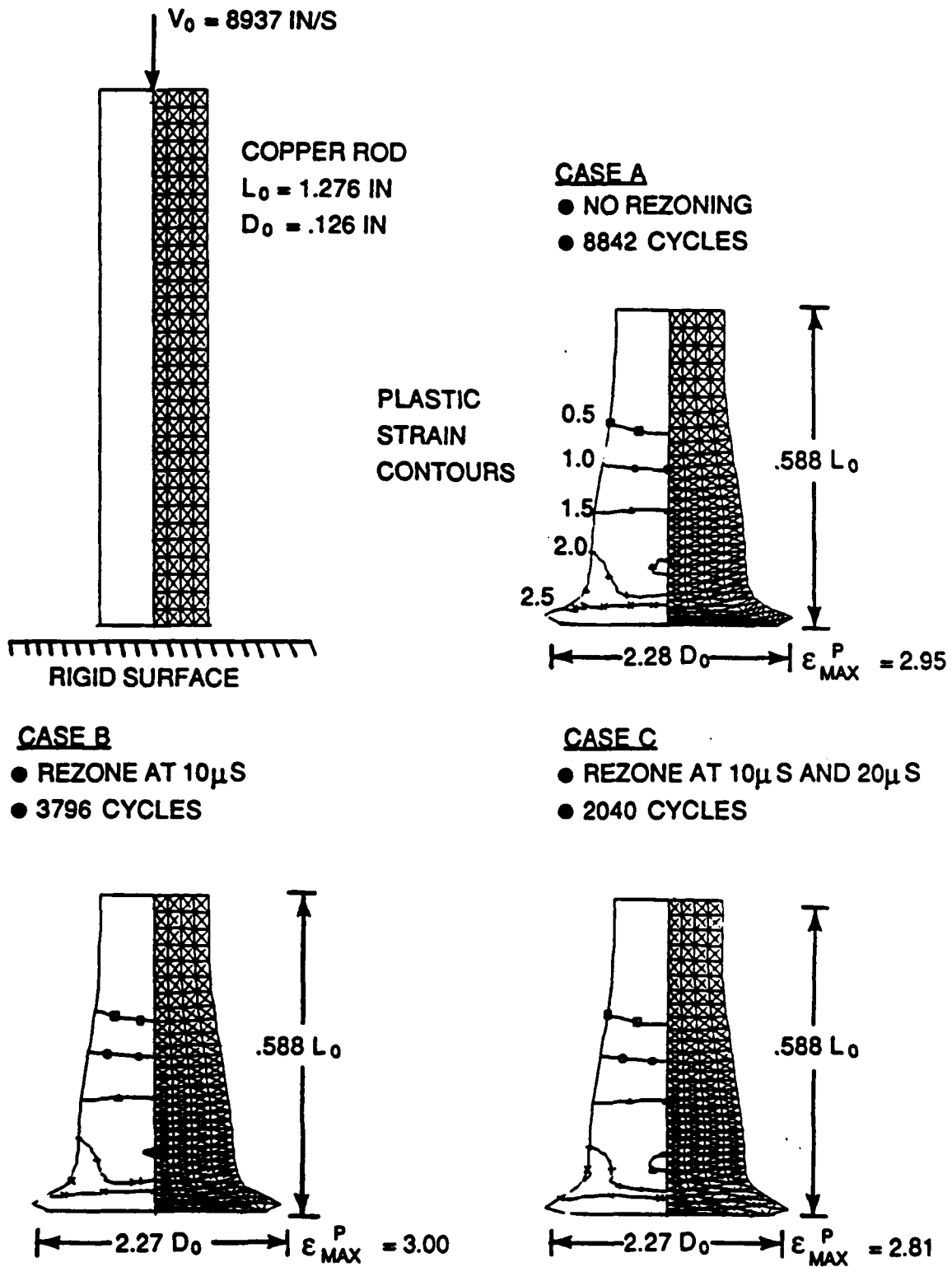


FIGURE 8. CYLINDER IMPACT EXAMPLE PROBLEM



It can be seen that the deformed lengths, the maximum deformed diameters, the strain contours and maximum strains are nearly identical for all three cases. The most significant difference occurs for the number of integration cycles. Here, the number of cycles is greatly decreased for the rezone runs, and this significantly decreases the required computing time.

EPIC-2 Preprocessor input data for the cylinder impact example are shown in Figure 9 and EPIC-2/REZONE input data for the rezone at 10 $\mu$ s are shown in Figure 10. The intent of this example is to demonstrate the conservation of properties after rezoning and the reduction in computing time.

An example of an explosive-metal interaction computation, with subsequent jet formation, is shown in Figure 11. For this problem, the severe distortions make it desirable to change the nodal connectivity such that there are more elements along the length of the jet. The resulting rezone then increases both the computational accuracy and the integration time increment.

EPIC-2 Preprocessor input data for the jet formation example are shown in Figure 12, and the corresponding EPIC-2/REZONE input data are shown in Figure 13. Some features of the grid, before and after rezoning, are shown in Figure 14.

```

101      2CYLINDER IMPACT EXAMPLE PROBLEM
  1      0      1      0      0      0      0      1
  1      0      1      0      999. COPPER

      1.0      1.0
  2      1      5      32      0      1      1.27559      0.      1.
.125984      0.      .125984      0.

      1.0      1.0
  2      1      1      4      31      5      1

      0.      -8937.      0.
0.5E-7      0.      1.
  0      0      1.      0.1E-8      0.9      .000080      1.0
  0      0      0      0
.000005      1111.      0.0      1
.000010      1111.      0.0      1
.000015      1111.      0.0      1
.000020      1111.      0.0      1
.000040      1111.      0.0      1
.000060      1111.      0.0      1
      1.      0.      0.0      1

```

FIGURE 9. EPIC-2 INPUT DATA FOR CYLINDER IMPACT EXAMPLE PROBLEM

```

CYLINDER REZONE AT 10 MICROSECONDS
$CYCL NPRJ NGN NGL NNDL NLDL PRNT
 209      0      1      1      284      496      0
$ N1G NLG INC
  1      284      1
$ L1G LLG INC
  1      496      1
$ FOUR-SIDED SHAPE NODES
$  7      N1      NC      NL IRFX/////      RELAX
  7      1      5      32      1      0.001
$NOLD NGEN      RCNR      ZCNR
  1
 280
 284
  5
$ IS1 IS2 IS3 IS4
  0      1      1      1
$ BLANK CARD (NOTE COLUMN 1 TO $ IS BLANK) FOR END OF NODES
$ FOUR-SIDED SHAPE ELEMENTS
$  7      N1 MATL L1 NCOL NLAY
  7      1      1      1      4      31
$ BLANK CARD (NOTE COLUMN 1 TO $ IS BLANK) FOR END OF ELEMENTS
$  TOLMRG
      0.0

```

FIGURE 10. EPIC-2/REZONE INPUT DATA FOR CYLINDER IMPACT EXAMPLE PROBLEM

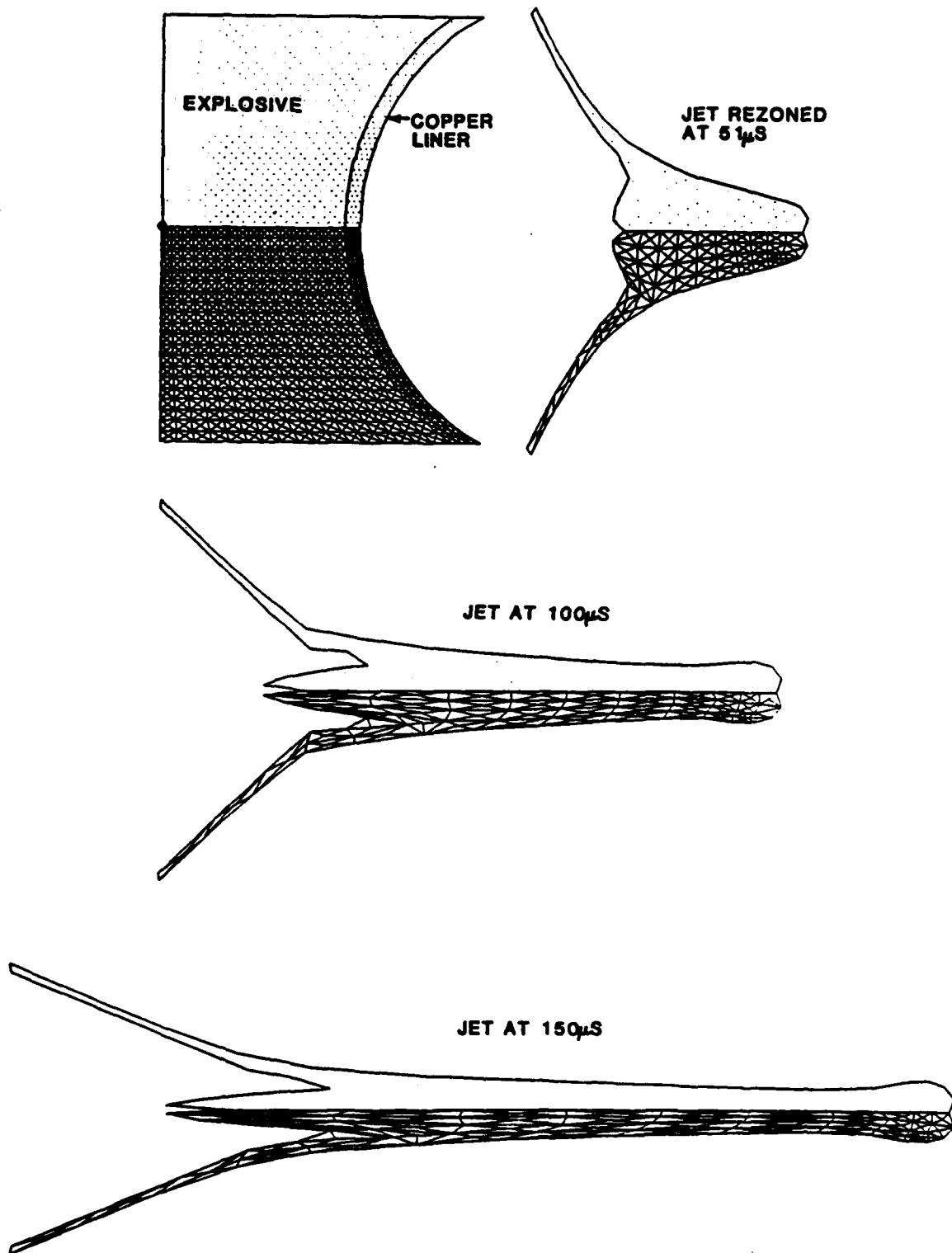


FIGURE 11. JET FORMATION EXAMPLE PROBLEM

```

1      2  EXAMPLE JET FORMATION PROBLEM
1      0      1      0      0      0      1
1      0      1      0      1.0 999.
41     0

      1.0      1.0
2      1      21      4      1      0.0      0.0      1.0
      2.0      0.0      2.0      0.0
1.8358      0.0      0.0      0.0      0.0      0.0      2.30
1.6858      0.0      0.0      0.0      0.0      0.0      2.45

      1.0      1.0
2      201      21      18      4      1      0.0      0.0      1.0
      2.0      0.0      2.0      0.0
1.6858      0.0      0.0      0.0      0.0      0.0      2.45
      0.0      0.0      0.0      0.0      0.0      0.0

2      1      1      20      3      5      1

2      201      41      20      17      5      301

21      21      1      1      2      1      1      0      0.0      0.5000E6      0.0
144      124      -1
201      221      1

      0.0      0.0      0.0      0.0      0.0      0.0      0.0
0.1E-7      0.0      1.0
0      1      1.0      0.1E-9      0.9      0.75E-4      1.0
0.5E-4      144      144      240      240

0
0.1E-4      1111.0      0.0      1
0.2E-4      1111.0      0.0      1
0.3E-4      1111.0      0.0      1
0.4E-4      1111.0      0.0      1
0.5E-4      1111.0      0.0      1
0.51E-4      1111.0      0.0      1
0.6E-4      1111.0      0.0      1
0.7E-4      1111.0      0.0      1
0.1E-0      0.0      0.0      1

```

FIGURE 12. EPIC-2 INPUT DATA FOR JET FORMATION EXAMPLE PROBLEM

```

JET FORMATION EXAMPLE PROBLEM
$CYCL NPRJ NGN NGL NNDL NLDL PRNT
788 0 1 1 144 240 0
$ NIG NLG INC
1 144
$ LIG LLG INC
1 240
$ REGRID LINE OF NODES
$ 9 N1 NN INC IRZT IS1
9 1 6 1 100 0
$NOLD NGEN RCNR ZCNR
1
124
$ THREE-SIDED SHAPE NODES FOR REGION A
$ 8 N1 NRNG/////IRFIX///// RELAX
8 7 5 1 0.01
$NOLD NGEN RCNR ZCNR
0 3
12
1
$ IS1 IS2 IS3
0 1 0
$ FOUR-SIDED SHAPE NODES FOR REGION B
$ 7 N1 NC NL IRFX///// RELAX
7 45 5 5 1 0.01
$NOLD NGEN RCNR ZCNR
3
5
16
12
$ IS1 IS2 IS3 IS4
0 0 1 0
$ FOUR-SIDED SHAPE NODES FOR REGION C
$ 7 N1 NC NL IRFX///// RELAX
7 104 5 3 1 0 0.01
$NOLD NGEN RCNR ZCNR
5
124
138
16
$ IS1 IS2 IS3 IS4
0 1 0 0
$ FOUR-SIDED SHAPE NODES FOR REGION D
$ 7 N1 NC NL IRFX///// RELAX
7 127 3 3 0 0.00
$NOLD NGEN RCNR ZCNR
16
138
141
18
$ IS1 IS2 IS3 IS4
0 1 0 1
$ REGRID LINE OF NODES IN REGION E
$ 9 N1 NN INC IRZT IS1
9 140 0 0 0 0
$NOLD NGEN RCNR ZCNR
80
$ FOUR-SIDED SHAPE NODES FOR REGION F
$ 7 N1 NC NL IRFX///// RELAX
7 141 3 2 0 0.01
$NOLD NGEN RCNR ZCNR
19
142
144
21
$ IS1 IS2 IS3 IS4

```

FIGURE 13. EPIC-2/REZONE INPUT DATA FOR JET FORMATION  
EXAMPLE PROBLEM

```

      0      3      0      3
$ OLD NODES
143
20
$ BLANK CARD (NOTE COLUMN 1 TO $ IS BLANK) FOR END OF NODES
$ THREE-SIDED SHAPE ELEMENTS FOR REGION A
$ 8  N1 MATL  L1 NCOL
  8  7  1  1  4
$ FOUR-SIDED SHAPE ELEMENTS FOR REGION B
$ 7  N1 MATL  L1 NCOL NLAY
  7  45  2  61  4  4
$ FOUR-SIDED SHAPE ELEMENTS FOR REGION C
$ 7  N1 MATL  L1 NCOL NLAY
  7  104  3  157  4  2
$ FOUR-SIDED SHAPE ELEMENTS FOR REGION D
$ 7  N1 MATL  L1 NCOL NLAY
  7  127  4  189  2  2
$ TRANSITION ELEMENTS FOR REGION E
$ 9  N1 MATL  L1  N2  N3  N4  N5  N6  N7  N8  N9  N10  N11  N12  N13
  9  140  5  205  129  134  139  146  141
$ FOUR-SIDED SHAPE ELEMENTS FOR REGION F
$ 7  N1 MATL  L1 NCOL NLAY
  7  141  6  210  2  1
$ BLANK CARD (NOTE COLUMN 1 TO $ IS BLANK) FOR END OF ELEMENTS
$ TOLMRG
  0.01

```

FIGURE 13. (Cont.)

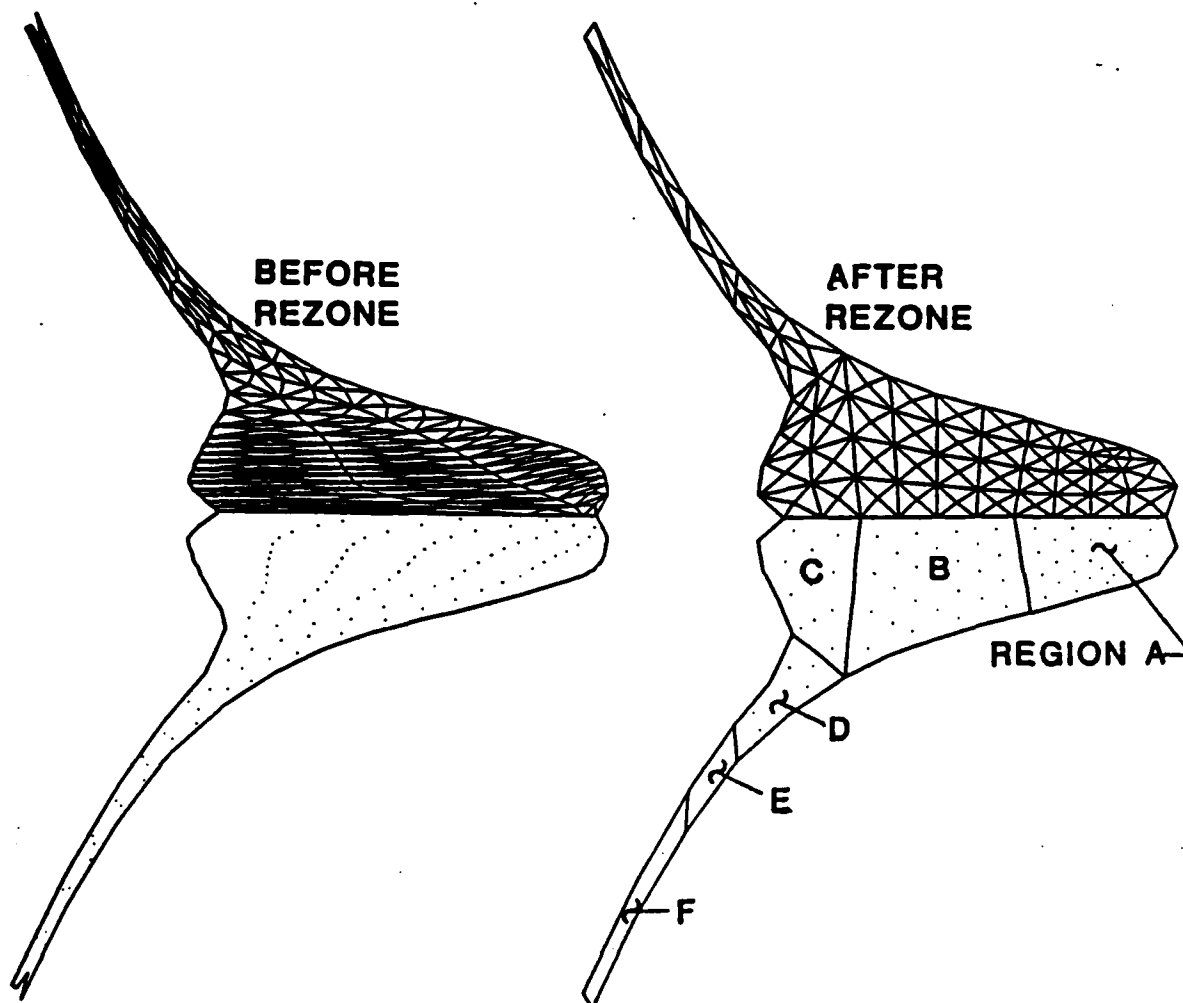


FIGURE 14. GRID IN THE JET BEFORE AND AFTER REZONING

**SECTION 4**

**CONCLUSIONS AND RECOMMENDATIONS**

User Instructions have been provided for the EPIC-2/REZONE code. The primary emphasis has been for jet formation computations, where it is anticipated that improvements can be realized for both accuracy and computing time.



## APPENDIX A

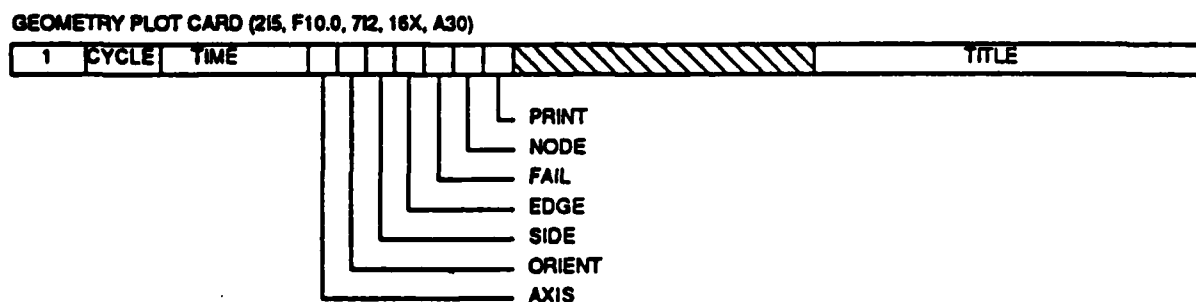
## EPIC-2 GEOMETRY STATE PLOTS WITH NODE NUMBERS

**The EPIC-2 Postprocessor for State Plots has been expanded to print node numbers on the geometry plots. This added capability is very helpful when rezoning. The modified data input for geometry plots are shown in Figure A-1. The variable PRINT has been added.**

**PRINT**       = 0 for no node numbers.  
              = 1 to print node numbers next to the nodes specified by the **NODE** option.

The drawn node numbers use the same size characters as those in the title. The user must choose the size of the graph to give readability. The node point is used as the lower left corner of the box in which the number is printed. Figure A-2 shows an example of this option, as used for the jet formation example problem

**Figure A-3 gives the modifications to EPIC-2/POST 1 in the VAX EDIT format, which will allow the node numbers to be printed. The variable IPRINT which is read in the POST 1 main program must be passed to subroutine GEOM and EXGEOM. In GEOM the calls to subroutine MAPRZ to plot projectile and target nodes are replaced by calls to a new subroutine MAPNOD. The subroutine MAPNOD is listed in Figure A-4.**



**FIGURE A-1. MODIFIED INPUT DATA FOR THE GEOMETRY PLOT CARD**

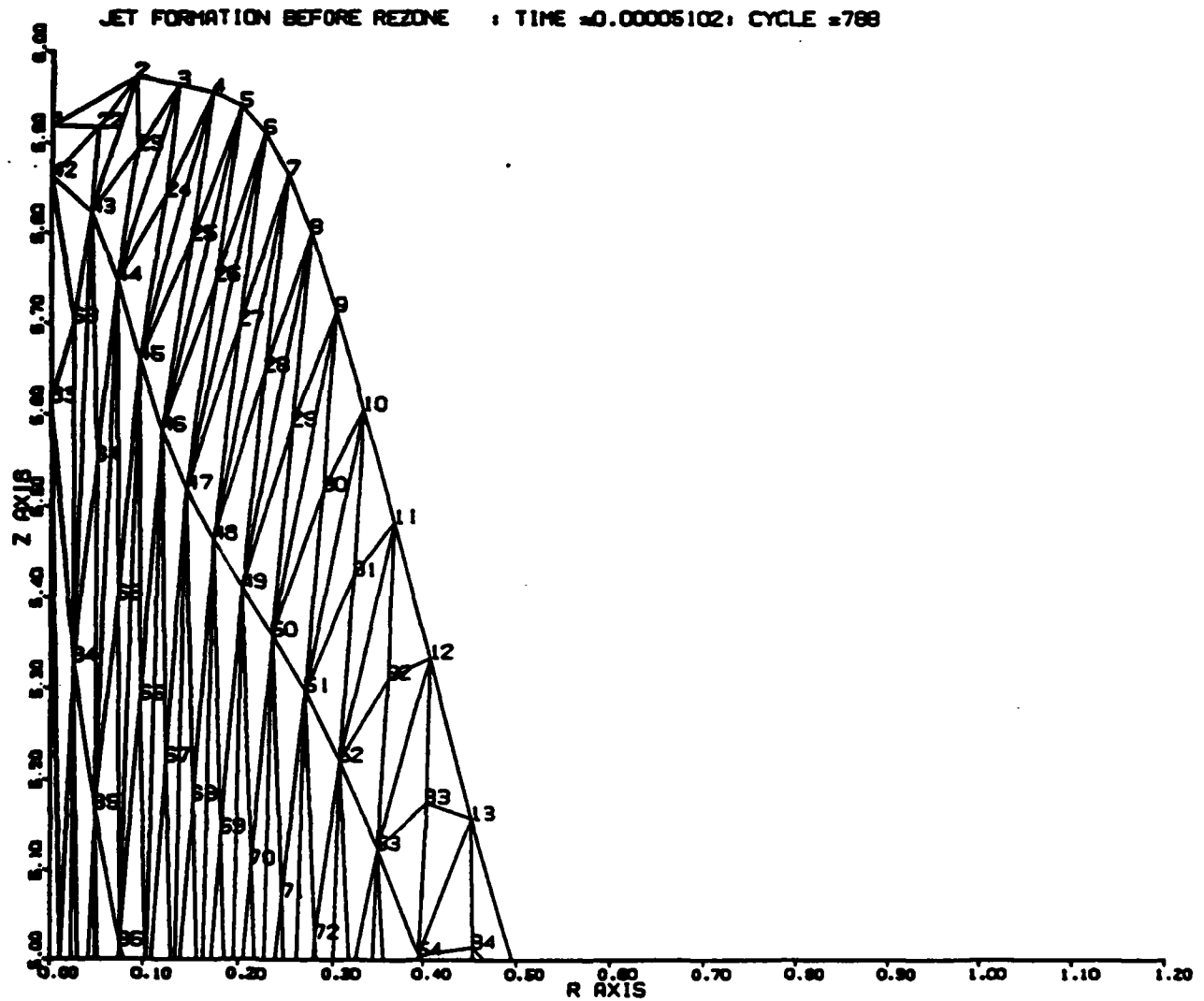


FIGURE A-2. DEFORMED GRID, WITH NODE NUMBERS, FOR THE JET BEFORE REZONING

```

INSERT      3;C POST1 revised for node number plotting 87/08/19
REPLACE    61;C      * IPRINT = 1 WILL PRINT NODAL QUANTITIES ON CONTOUR PLOTS
INSERT     62;C      * AND PLOT NODE NUMBERS NEXT TO NODES FOR IPNT.NE.0
INSERT      ;C      * ON GEOMETRY PLOTS
SUBSTITUTE/IPNT/IPNT,IPRINT/ 330
SUBSTITUTE/IPNT/IPNT,IPRINT/ 100384
SUBSTITUTE/IPNT,TITLE/IPNT,IPRINT/ 2902421
SUBSTITUTE/RMAX/                               TITLE,RMAX/                2902422
REPLACE 2902423;C      REV 87/05/11
SUBSTITUTE/IPNT/IPNT,IPRINT/ 2902486
SUBSTITUTE/IPNT/IPNT,IPRINT/ 2902707
REPLACE 2902709;C      REV 87/05/11
INSERT 2902727;      INTEGER IPRINT
INSERT      ;C      * IPRINT FLAGS NODE PRINTING OPTION
SUBSTITUTE/ PLOT THE NODE// 2902766
INSERT 2902767;C      PLOT THE NODE
INSERT      ;C      IF IPRINT SET THEN PLOT NODE NUMBER
SUBSTITUTE/ PLOT THE NODE// 2902768
INSERT 2902769;C      PLOT THE NODE
INSERT      ;C      IF IPRINT SET THEN PLOT NODE NUMBER
REPLACE 2902999;      CALL MAPNOD(NNX,LINTYP,NSYM,IPRINT)
REPLACE 2903010;      CALL MAPNOD(NNX,LINTYP,NSYM,IPRINT)
EXIT POST1.FOR/SEQUENCE

```

FIGURE A-3. MODIFICATIONS TO EPIC-2/POST 1 TO ALLOW FOR NODE  
NUMBER PLOTTING

```

C      SUBROUTINE MAPNOD(NA,LINTYP,NSYM,IPRINT)
C      * REVISED 87/05/11
C      * MAPNOD A NODE ONTO THE GRAPH AND OPTIONALLY PRINT NODE NUMBER
C      INTEGER NA,LINTYP,NSYM,IPRINT
C
C      * CALLS WINDOW
C      * CALLED BY GEOM
C      * LATEST REVISION MAY 1987
C      CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C      *IF PLOT TO RIGHT OF Z AXIS THEN
C      *IF PLOT NOT ROTATED THEN
C      *   PLOT NORMAL NODE
C      *   *IF IPRINT SET THEN
C      *   *   PRINT NODE NUMBER WHEN ON GRAPH
C      *   *ENDIF
C      *   *ELSE AXIES ROTATED
C      *   *   PLOT ROTATED NODE
C      *   *   *IF IPRINT SET THEN
C      *   *   *   PRINT NODE NUMBER WHEN ON GRAPH
C      *   *   *ENDIF
C      *   *ENDIF ROTATED
C      *ENDIF RIGHT
C      *IF PLOT TO LEFT OF Z AXIS THEN
C      *IF PLOT NOT ROTATED THEN
C      *   PLOT MIRROR NODE
C      *   *IF IPRINT SET THEN
C      *   *   PRINT NODE NUMBER WHEN ON GRAPH
C      *   *ENDIF
C      *   *ELSE AXIES ROTATED
C      *   *   PLOT ROTATED MIRROR NODE
C      *   *   *IF IPRINT SET THEN
C      *   *   *   PRINT NODE NUMBER WHEN ON GRAPH
C      *   *   *ENDIF
C      *   *ENDIF ROTATED
C      *ENDIF LEFT
C      CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C      LOGICAL AXROT
C      * AXROT INDICATED AXIAL ROTATION (R,Z TO Z,-R)
C      LOGICAL LEFT
C      * LEFT INDICATES TO PLOT TO LEFT OF Z AXIS (NEGATIVE R)
C      REAL R
C      * R IS THE RADIAL COORDINATE OF A NODE
C      LOGICAL RIGHT
C      * RIGHT INDICATES TO PLOT TO RIGHT OF Z AXIS (POSITIVE R)
C      REAL X
C      * X CONTAINS HORIZONTAL INFORMATION
C      * X(3),X(4) ARE SCALING INFO FROM SCALE CALL EARLIER
C      REAL Y
C      * Y CONTAINS VERTICAL INFORMATION
C      REAL Z
C      * Z IS THE Z COORDINATE OF A NODE
C
C      MXND IS THE MAXIMUM NUMBER FOR NODES
C      PARAMETER MXND=1000
C      COMMON/NODE/R(MXND),Z(MXND),RDOT(MXND),ZDOT(MXND),TDOT(MXND),
C      & AHASS(MXND),PHASS(MXND),COUNT(MXND),PNEW(MXND),NODE(MXND),
C      & SPAREN(MXND),NODP(MXND),GRX(MXND),R0(MXND),VERT(MXND)
C      COMMON /CHAP/ AXROT,LEFT,RIGHT,X(4),Y(4),HLONG,VLONG,
C      & HMIN,HMAX,VMIN,VMAX
C
C      RNA = NA
C      *IF PLOT TO RIGHT OF Z AXIS THEN
C      *   IF(.NOT.RIGHT)GOTO 1
C      *   *IF PLOT NOT ROTATED THEN
C      *   *   IF(AXROT)GOTO 2
C      *   *   PLOT NORMAL NODE

```

FIGURE A-4. LISTING OF SUBROUTINE MAPNOD TO ALLOW FOR NODE NUMBER PLOTTING

```

      CALL WINDOW(R(NA),Z(NA),R(NA),Z(NA),LINTYP,NSYM)
C      *IF IPRINT SET THEN
      IF(IPRINT.EQ.1)THEN
1        IF(R(NA).GE.HMIN .AND. R(NA).LE.HMAX .AND.
          Z(NA).GE.VMIN .AND. Z(NA).LE.VMAX)THEN
          XPAGE = (R(NA)-X(3))/X(4)
          YPAGE = (Z(NA)-Y(3))/Y(4)
          CALL NUMBER(XPAGE,YPAGE,0.14,RNA,0.0,-1)
        ENDIF
      ENDIF
      GOTO 3
C      *ELSE AXIES ROTATED
C      PLOT ROTATED NODE (Z(NA),-R(NA))
C      2 CALL WINDOW(Z(NA),-R(NA),Z(NA),-R(NA),LINTYP,NSYM)
C      *IF IPRINT SET THEN
      IF(IPRINT.EQ.1)THEN
1        IF(Z(NA).GE.HMIN .AND. Z(NA).LE.HMAX .AND.
          -R(NA).GE.VMIN .AND. -R(NA).LE.VMAX)THEN
          XPAGE = (Z(NA)-X(3))/X(4)
          YPAGE = (-R(NA)-Y(3))/Y(4)
          CALL NUMBER(XPAGE,YPAGE,0.14,RNA,0.0,-1)
        ENDIF
      ENDIF
C      *ENDIF ROTATED
C      3 CONTINUE
C      *ENDIF RIGHT
C      *IF PLOT TO LEFT OF Z AXIS THEN
C      1 IF(.NOT.LEFT)GOTO 11
C      *IF PLOT NOT ROTATED THEN
      IF(AXROT)GOTO 12
C      PLOT MIRROR NODE (-R(NA),Z(NA))
      CALL WINDOW(-R(NA),Z(NA),-R(NA),Z(NA),LINTYP,NSYM)
C      *IF IPRINT SET THEN
      IF(IPRINT.EQ.1)THEN
1        IF(-R(NA).GE.HMIN .AND. -R(NA).LE.HMAX .AND.
          Z(NA).GE.VMIN .AND. Z(NA).LE.VMAX)THEN
          XPAGE = (-R(NA)-X(3))/X(4)
          YPAGE = (Z(NA)-Y(3))/Y(4)
          CALL NUMBER(XPAGE,YPAGE,0.14,RNA,0.0,-1)
        ENDIF
      ENDIF
      GOTO 13
C      *ELSE AXIES ROTATED
C      PLOT ROTATED MIRROR NODE (Z(NA),R(NA))
C      12 CALL WINDOW(Z(NA),R(NA),Z(NA),R(NA),LINTYP,NSYM)
C      *IF IPRINT SET THEN
      IF(IPRINT.EQ.1)THEN
1        IF(Z(NA).GE.HMIN .AND. Z(NA).LE.HMAX .AND.
          R(NA).GE.VMIN .AND. R(NA).LE.VMAX)THEN
          XPAGE = (Z(NA)-X(3))/X(4)
          YPAGE = (R(NA)-Y(3))/Y(4)
          CALL NUMBER(XPAGE,YPAGE,0.14,RNA,0.0,-1)
        ENDIF
      ENDIF
C      *ENDIF ROTATED
C      13 CONTINUE
C      *ENDIF LEFT
C      11 RETURN
      END

```

FIGURE A-4. (Cont.)

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